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13. ABSTRACT (Maximum 200 words)
Detailed molecular structural information is of enormous significance to the medical and biological communities. Since hydrated biologically active structures are small delicate complex three-dimensional (3D) entities, it is essential to have molecular scale spatial resolution, high contrast, distortionless, direct 3D modalities of visualization of specimens in the living state in order to faithfully reveal their full molecular architectures. An x-ray holographic microscope equipped with an x-ray laser as the illuminator would be uniquely capable of providing these images. The findings presented in this report (1) experimentally demonstrate at $\lambda \cong 2.9$ Å the operation of a new concept capable of producing the ideal conditions for amplification of multikilovolt x-rays and (2) prove the feasibility of a compact x-ray illuminator that can cost-effectively achieve the mission of x-ray biological microholography and likewise serve an array of other applications involving the fabrication and measurement of solid state nanostructures. An estimate of the peak brightness achieved in these initial experiments gives a value of $\sim 10^{29}\ \gamma\cdot s^{-1}\cdot mm^{-2}\cdot mr^{-2}(0.1\%\ \text{Bandwidth})^{-1}$, a magnitude that is $\sim 10^5$-fold higher than presently available synchrotron technology.

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FINAL PROGRESS REPORT
DAAG55-97-1-0310

Studies of Dynamically Enhanced Electromagnetic Coupling in Self-Trapped Channel
Award End Date: 4 May 2000

(1) FOREWORD

Ideal conditions for x-ray amplification in the multikilovolt spectral region combine an exceptional set of circumstances. They are summarized by the production of cold, low opacity, spatially directionally organized, and vigorously (10^{19}–10^{20} W/cm^3) inner-shell state-selectively excited high-Z matter. The results reported below establish that the alliance of two recently studied phenomena, (α) the direct multiphoton excitation of hollow atoms from clusters with ultraviolet radiation and (β) a nonlinear mode of confined propagation in plasmas resulting from relativistic/charge-displacement self-channeling, can successfully produce the union of this demanding set of requirements. Experimental evidence and corresponding theoretical analyses have led to the conclusion that the hollow atom Xe(L) emission at $\lambda \cong 2.9$ Å generated by 248 nm excitation of Xe clusters in a self-trapped channel closely represents the ideal conditions sought for x-ray amplification. Specifically, on the basis of (a) a detailed examination of Xe(L) spectral data, (b) theoretical analyses of the mechanisms of cluster excitation and channeled propagation, and (c) calibrated measurements of the Xe(L) energy yield, the exponential gain constant g_L is estimated to reach a value of $g_L = 60 \pm 20$ cm^{-1}, a range approximately two orders of magnitude above the competing absorptive losses. The measurements described herein confirm these assessments.

Detailed molecular structural information is of enormous significance to the medical and biological communities. Since hydrated biologically active structures are small delicate complex three-dimensional (3D) entities, it is essential to have molecular scale spatial resolution, high contrast, distortionless, direct 3D modalities of visualization of specimens in the living state in order to faithfully reveal their full molecular architectures. An x-ray holographic microscope equipped with an x-ray laser as the illuminator would be uniquely capable of providing these images [1,2]. The findings presented in this report (1) experimentally demonstrate at $\lambda \cong 2.9$ Å the operation of a new concept capable of producing the ideal conditions for amplification of multikilovolt x-rays and (2) prove the feasibility of a compact x-ray illuminator that can cost-effectively achieve the mission of x-ray biological microholography and likewise serve an array of other important applications involving the fabrication and measurement of solid state nanostructures. An estimate of the peak brightness achieved in these initial experiments gives a value of ~ $10^{29}\gamma\cdot s^{-1}\cdot mm^{-2}\cdot mr^{-2}(0.1\%\ \text{Bandwidth})^{-1}$, a magnitude that is ~$10^5$-fold higher than presently available synchrotron technology [3].

(2), (3) NA.

(4) STATEMENT OF PROBLEM STUDIED

The development of methods for the compression of power in materials is one of the oldest endeavors of mankind with an origin that precedes the Stone Age. From the use of a wooden club to the contemporary production of vigorous thermonuclear environments, the achievable power density (W/cm^3) has been advanced by approximately a factor of 20 orders of magnitude (~ 10^{20}). New processes, involving the nonlinear interaction of intense (~ 10^{18}–10^{21} W/cm^2) fs pulses of radiation with matter were explored to enhance further the controlled production of these environments to a new ultrahigh level (~ 10^{19}–10^{21} W/cm^3), a range that can approach ≈ 100 W/atom.

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(5) SUMMARY OF THE MOST IMPORTANT RESULTS
See attached paper.

(6) LIST OF PUBLICATIONS

1. "Energetic Electronic Ensembles: New Rules for the Interaction of Radiation with Matter," C. K. Rhodes and G. Marowsky, *Appl. Phys.* B66, 475 (1998).
2. "Theoretical/Experimental Studies of Ultraviolet High-Power Density Self-Trapped Channels," A. B. Borisov, B. D. Thompson, A. McPherson, F. Omenetto, T. Nelson, W.A. Schroeder, K. Boyer, and C. K. Rhodes, in *Superstrong Fields in Plasma*, edited by M. Lontano et al. (American Institute of Physics, New York, 1998) p.322.
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9. "Hollow Atom Production By a Shell-Selective Collisional Ejection Process in Clusters and Solids Xe(L) and Ba(L)," Thomas R. Nelson, A. B. Borisov, S. Cameron, J. W. Longworth, T. S. Luk, W. A. Schroeder, J. Santoro, A. J. VanTassle, and C. K. Rhodes, X-Ray and Inner-Shell Processes, Chicago, 1999.

10. "An Efficient, Selective Collisional Ejection Mechanism for Inner-Shell Population Inversion in Laser Driven Plasmas," W. A. Schroeder, T. R. Nelson, A. B. Borisov, J. W. Longworth, K. Boyer, and C. K. Rhodes, submitted to *J. Phys.* B.
11. "Bifurcation Mode of Relativistic and Charge-Displacement Self-Channeling," A. B. Borisov, S. Cameron, T. S. Luk, T. R. Nelson, A. Van Tassle, J. Santoro, W. A. Schroeder, Y. Dai, J. W. Longworth, K. Boyer, and C. K. Rhodes, submitted to *J. Phys.* B, May, 2000.

(7) PARTICIPATING SCIENTIFIC PERSONNEL

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(8) INVENTIONS

No inventions reported.

(9) BIBLIOGRAPHY

See attached paper.

(10) NA.